Chapter 3.9
Modeling Scalable Grid Information Services with Colored Petri Nets

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ABSTRACT

Information services play a crucial role in grid computing environments in that the state information of a grid system can be used to facilitate the discovery of resources and services available to meet user requirements and help tune the performance of the grid. This paper models PIndex, which is a grouped peer-to-peer network with Colored Petri Nets (CPNs) for scalable grid information services. Based on the CPN model, a simulator is implemented for PIndex simulation and performance evaluation. The correctness of the simulator is further verified by comparing the results computed from the CPN model with the results generated by the PIndex simulator.

INTRODUCTION

The past few years have witnessed a rapid development of grid computing infrastructures and applications (Li & Baker, 2005; Wang, Helian, Wu, Deng, Khare, & Thompson, 2007; Wang, Wu, Helian, Parker, et al. 2007; Wang, Wu, Helian, Xu, 2007). Information services play a crucial role in grid environments in that they facilitate the discovery of resources and services (Czajkowski, Kesselman, Fitzgerald, & Foster, 2001). Information services periodically collect data on available resources including hardware and software in a grid environment. The data can then be used by a number of elements in a grid to keep the grid running smoothly. For example, job schedulers use resource information to make adaptive decisions

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on allocating resources to jobs to achieve certain goals such as a minimum make-span in execution of jobs (Berman et al., 2003).

Grid middleware technologies facilitate information services. For example, the current Globus Toolkit (http://www.globus.org) provides a component called the Monitoring and Discovery System version 4 (MDS4) (Schopf et al., 2006) for resource registration and discovery. The MDS4 component adopts a hierarchical tree structure to distribute its monitoring data on resources across a virtual organization (VO), in which every node runs an index service monitoring its resources and pushing this information up to a master index server. A query to the top Index server could retrieve all the information on the resources available in a VO. The Relational Grid Monitoring Architecture (R-GMA) (Cooke et al., 2004), which is now a component of the gLite middleware (http://www.cern.ch/glite), also facilitates resource registration and discovery. It is worth noting that grids differentiate themselves from traditional distributed systems in the following aspects:

- The size of a grid is usually large in terms of the number of computing nodes involved.
- Resources in a grid are usually heterogeneous with various computing capabilities and services.
- A grid is dynamic in that computing nodes may join or leave a grid freely. In addition, some resources such as the CPU load of a grid node may change frequently.

The aforementioned characteristics of grids bring forth a number of challenges to existing information services, notably the MDS4 and the R-GMA. The hierarchical structure along with centralized management of MDS4 has an inherent delay associated with it which potentially limits its scalability in resource registration. It might take a long time for resource information to be updated from the leaf nodes to the root index service node. Cai, Frank, Chen, and Szekely (2004) point out that the scheme to partition resource information on index servers is typically predefined and cannot adapt to the dynamic changes of VOs. The MDS4 also lacks a mechanism to deal with failures of index servers which may break the information service network into isolated subnets. The R-GMA contains a centralized registry (Groep, Templon, & Loomis, 2006), and performs poorly when dealing with only 100 consumer nodes (Zhang, Freschl, & Schopf, 2007).

In parallel development with grid computing, peer-to-peer (P2P) computing has merged into another promising computing paradigm that typically facilitates file sharing in large network environments (Milojicic et al., 2002). P2P networks usually organize peer nodes in a decentralized way, and the reliability can be enhanced by replication of shared files among peer nodes. Files can be arbitrarily distributed into peer nodes without a structure, or they are distributed following a structure such as Distributed Hash Table (DHT). DHT based P2P networks such as Chord (Stoica et al., 2002), Pastry (Rowstron & Druschel, 2001), CAN (Ratnasamy, Francis, Handley, Karp, & Shenker, 2001) have shown enhanced scalability in routing lookup messages for files with a guaranteed number of hops. Foster and Iamnitchi (2003) analyzed the differences between P2P and grid computing and discussed a possible convergence of the two computing paradigms. Talia and Trunfio (2003) pointed out the benefits that P2P networks could bring to grid systems in terms of scalability and robustness. However, directly applying DHT technologies to grid information services mainly poses two challenges. On the one hand, DHT systems usually incur high maintenance overhead in dealing with *churn* situations where peer nodes may join or leave P2P networks at high rates (Godfrey, Shenker, & Stoica, 2006; Rhea, Geels, Roscoe, & Kubiatowicz, 2004). On the other hand, DHT based P2P networks only support exact matches for files using single hash keys. In a grid environment, it is not realistic to employ a single hash key for a

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